Sustainment *Interoperability*

SE Process
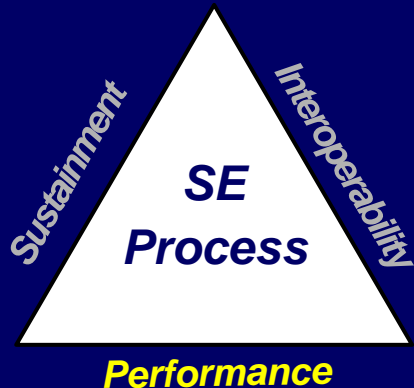
Performance

Successes and Pitfalls with Introduction of COTS in the Aegis Weapon System

(The Good, the Bad, and the Ugly – and the Challenge)

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Dahlgren, Virginia

NDIA System Engineering Conference Oct 21-24 2002

Outline

- **Aegis Combat System**

- **Introduction of COTS**

- **COTS - Theory / Reality**

- **COTS – Good, Bad and Ugly**

- **COTS - The Challenge**

  - **Infrastructure**

  - **Engineering**

- **Summary**

Aegis Is . . .

➢ **Aegis Weapon System (AWS)**

    ➢ **U.S. Navy's most advanced shipboard anti-air warfare (AAW) weapon system**

        - *Detection, Control and Engagement for Air Targets*

➢ **Aegis Combat System (ACS)**

    ➢ **A highly integrated ship combat system, built around the AWS**

    ➢ **Capable of simultaneous warfare on several fronts**
    - **Air, Surface, Subsurface, and Strike Warfare**

    ➢ *Evolving Requirements Drive Continual Improvements via Baseline Upgrade Program*

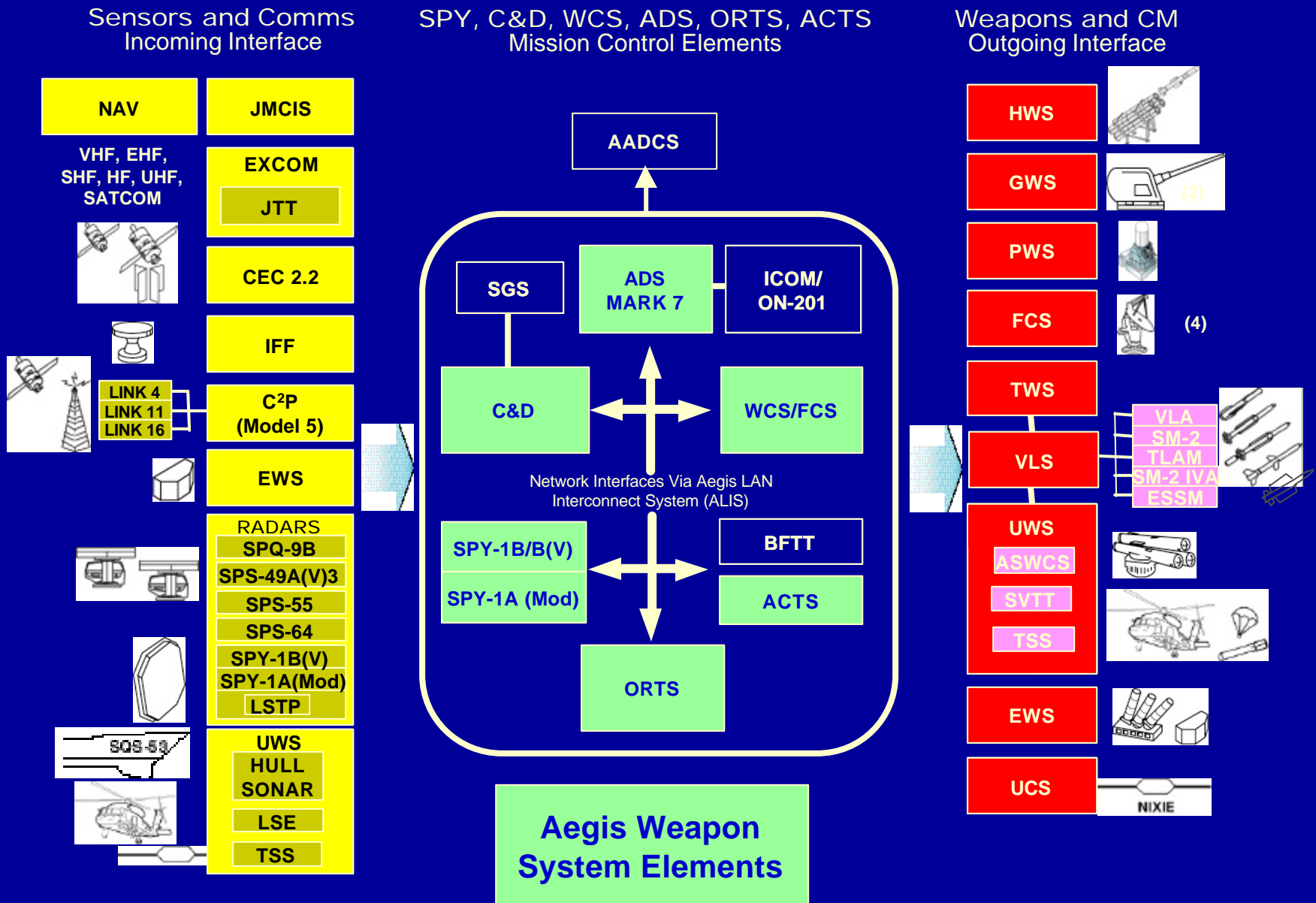➢ **A long-standing Development/Production/Shipbuilding program**

    ➢ **Aegis (Ticonderoga) CG 47 Class Cruisers – deployed**

    ➢ **Aegis (Arleigh Burke) DDG 51 Class Destroyers – deployed and in construction**

    ➢ **Aegis ships are front-line surface combatants that played a critical role in Operation Desert Storm and currently operate in international peacekeeping efforts around the globe**
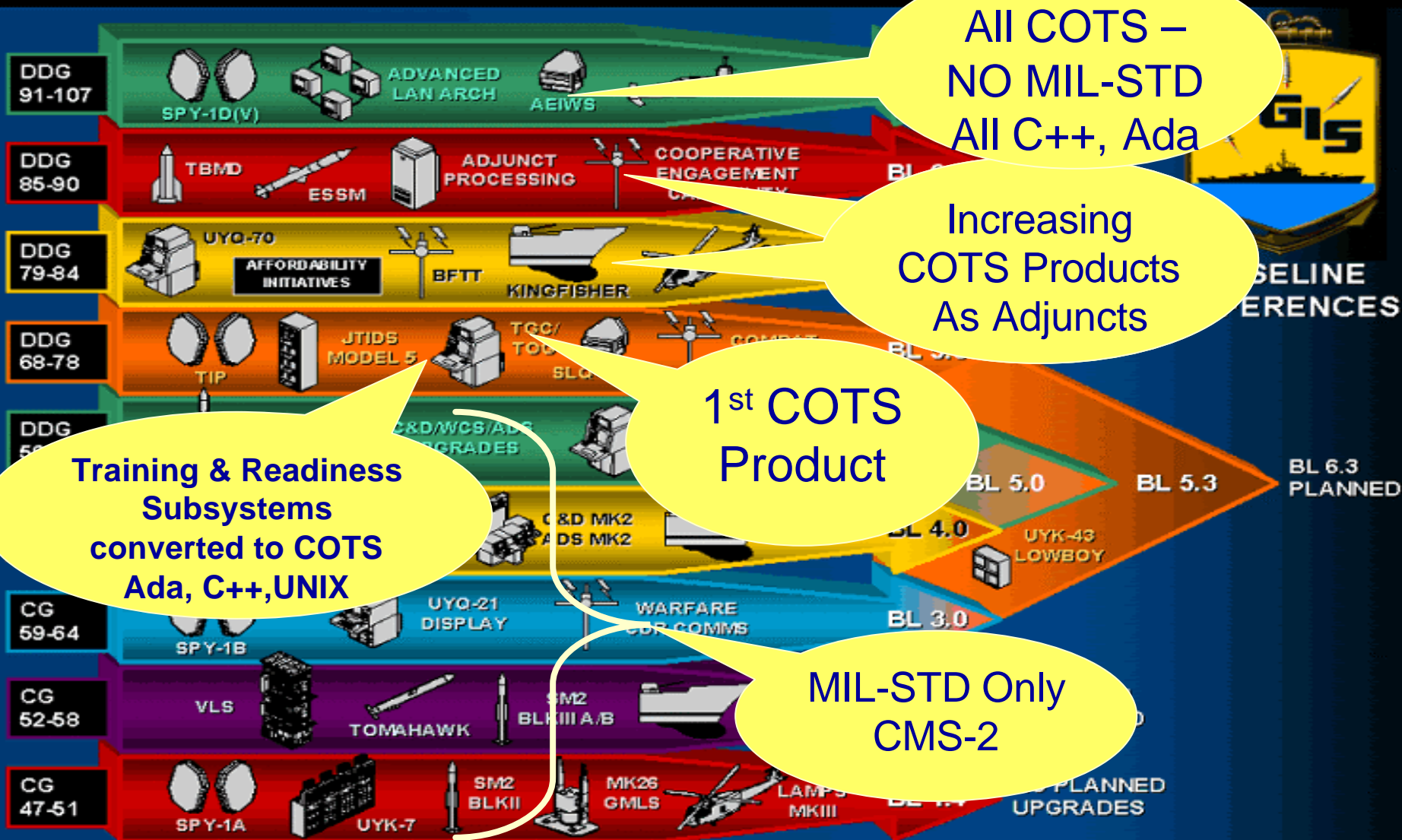
➢ **The backbone of the most powerful fleet on earth**

    ➢ **Aegis represents the significant majority of the Surface Combatant Fleet through 2030**

Example of Aegis Combat System Configuration

Sensors and Comms
Incoming Interface

SPY, C&D, WCS, ADS, ORTS, ACTS
Mission Control Elements

Weapons and CM
Outgoing Interface

NAV	JMCIS

VHF, EHF, SHF, HF, UHF, SATCOM

EXCOM

JTT

CEC 2.2

IFF

LINK 4
LINK 11
LINK 16

C²P (Model 5)

EWS

RADARS
SPQ-9B
SPS-49A(V)3
SPS-55
SPS-64
SPY-1B(V)
SPY-1A(Mod)
LSTP

UWS
HULL SONAR
LSE
TSS

AADCS

SGS

ADS MARK 7

ICOM/ ON-201

C&D

WCS/FCS

Network Interfaces Via Aegis LAN Interconnect System (ALIS)

SPY-1B/B(V)

SPY-1A (Mod)

BFTT

ACTS

ORTS

Aegis Weapon System Elements

HWS

GWS

PWS

FCS

(4)

TWS

VLS

VLA
SM-2
TLAM
SM-2 IVA
ESSM

UWS
ASWCS
SVTT
TSS

EWS

UCS

NIXIE

Aegis Baseline Progression

COTS – The Theory

- **Lower development costs**

- **Faster development**

- **Leverage the efforts (and mistakes) of many others**

- **Leverage new technology, stay in the mainstream**

- **Lower life cycle maintenance costs**

COTS – The Reality

COTS Monster Sighted

By The Associated Press

ATLANTIC OCEAN - This amazing and rare photograph was taken by a Navy C-130 pilot shortly after dropping NSWC Dahlgren's Clark Henshaw to DDG-81 with the latest Operating Environment Restore Tapes. Mr. Henshaw bravely strapped on a parachute and stuffed 42 DAT tapes in his pockets to make the delivery. He was quoted as saying, " boy that large ship looks pretty small from 5000 feet." The COTS monster has only been sighted in recent years. He raises his head from the depths of the sea anytime a circuit card is changed, a program crashes, or reconfiguration is required.

The Navy is currently working on a powerful tool to combat the COTS monster called MTT/ASVADS. However, at this time the tool set has not been deployed. Until these tools can be delivered to the fleet, brave men and women like Mr. Henshaw will continue to jump to keep our Navy ships operational. Mr. Henshaw and his group of skydivers stand ready for all future deliveries.

COTS - The GOOD
For the Development Team

- **COTS offers tremendous computational resources to the Aegis System**
  - Development teams that were constrained by the MIL-STD systems save valuable time and resources not trying to "cram" the desired functionality into very limited space and optimizing code.

- **Purchase Cost is significantly less than Development Cost**

- **Time - Lots of Functionality available in months vice years**

- **Significant improvements in HSI**

- **With COTS, extensible designs are possible, making modifications easier**
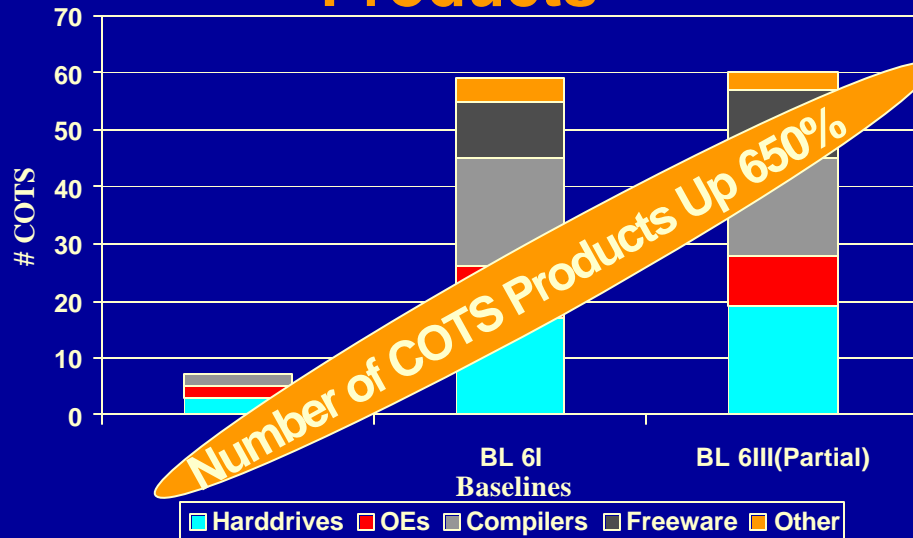

AEGIS Mission Success
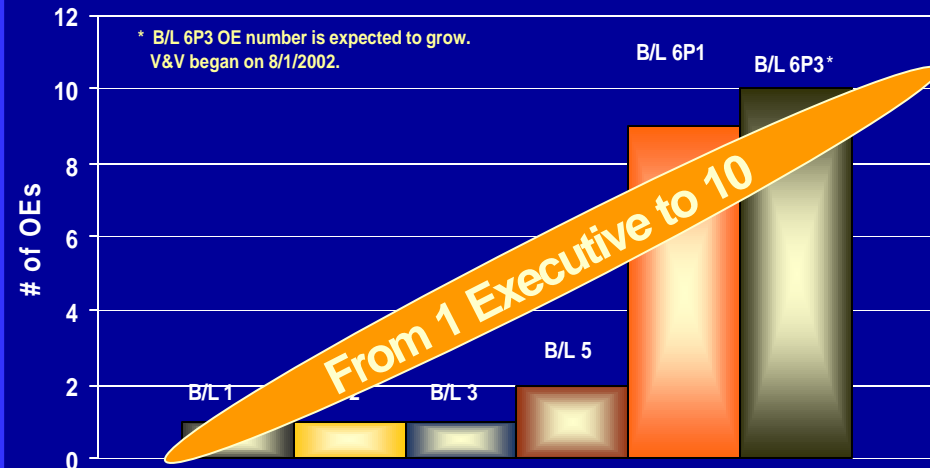
COTS – The BAD
For the Builder/Installer

- With COTS, the size of an Aegis baseline has mushroomed from 5 MSLOC (source lines of code) to several times this size.

- Even though a lot of it is COTS, and was "cheap", it still must be configuration managed, built, delivered and installed.

- Delivery and Installation of OE and Applications

  - We have moved from the ability to "FedEx" a computer program upgrade to a ship, to a "delivery" process that is much more complicated, with version control extending to "tuning" changes that must be made aboard ships (OE, LAN addresses, MAC addresses, routers, flash cards, etc.).

- System skills required for COTS are at least as significant as for Legacy software development

- The money "Saved" in development from using COTS did NOT result in more money for maintenance.

Increasing # of COTS Products

Number of COTS Products Up 650%

Chart — # COTS (y-axis 0 to 70) by Baselines: BL 6I, BL 6III(Partial)

Legend: Harddrives ■ OEs ■ Compilers ■ Freeware □ Other ■

Growth in Operating Environments

* B/L 6P3 OE number is expected to grow. V&V began on 8/1/2002.

From 1 Executive to 10

Chart — # of OEs (y-axis 0 to 12): B/L 1, B/L 2, B/L 3, B/L 5, B/L 6P1, B/L 6P3*

Growth of Elements from VAX platform to UNIX platform

Manual V&V of Files is No Longer Possible

	FILES	SIZE
•ADSMK2	1,227	491,11_
•ADSMK6	26,347	3,_ _ _cks
•ATES/43(Excl. Adjunct)	1,700	_ _ Blocks
•ATOE	22_	_,053 Blocks
•ACTSMK29		131,053 Blocks
•ACTS Rehost		89,626 Blocks
•ORTS/MK7	_232	98,146 Blocks
•ORTS/MK9	19,267	1,658,940 Blocks
TOT_ _ BL 5	3,381	984,703 Blocks
BL 6	46,553	5,269,020 Blocks

Manhours for Baselines 5.3.8 and 6.1 Build Process

Build Effort is Up By 140%

	Baseline 5.3.8	Baseline 6
Elements	36	60
CPM	140	
SPM	202	265
Doc	202	287
Fleet Support		40
QC	_9	766
Total:	769	1833

COTS – The UGLY
For the Maintainer

- **Loss of Control of Changes (Driven by Marketplace)**
  - Limited visibility into COTS code

- **Uncertainty about What You're Getting**
  - No Error Disclosure
  - Limited control of frequency or content of COTS releases
  - Not Getting Fixes When Needed or Getting Some Fixes That Were Not Needed

- **Vendor Abandoning Product or Going out of Business – no longer "Off the Shelf"**

- **License Management**

- **Risk**
  - Complicates Testing
  - Small Percentage Actually Tested
  - Complex and unnecessary features must execute anyway, consuming machine cycles and increasing the likelihood of failures.
    - Feature bloat tends to make the COTS software very complex to use, configure and maintain.

AEGIS Mission Failure

COTS – Challenge

Infrastructure:

- **Business - Policies, Guidelines, Planning**
- **Methods - Process, Tools, Configuration Management**
- **Training**

Technical:

- **Testbeds for Replacement Components**
- **Certification**
- **Security**

PEO TSC CI/NDI Policy Instruction (PEOTSCINST 4890.1) and Management Plan

1. INTRODUCTION

1.1. PURPOSE

Effective management of Commercial Items/Non-D challenging and critical to program success and int exponential rate of change in technology developme the life of a program. This Management Plan ("Plan Instruction (PEOTSCINST 4890.1) to assist the PE insertion and support of non-military items into S framework to develop, execute, and manage a c acquisition, integration and life cycle support encompassing strategy, but rather to sugges mission requirements.

PEO TSC has Developed An Instruction and Management Plan to aid in the Insertion and Support of COTS Products

-

Performance vs. Lifetime Cost

1.2. SCOPE

This Plan will help users decide "WHAT" factors to consider when designing and integrating CI/NDI. PEO TSC acquisition objectives are to obtain products:

- **that work as intended in their designated environment,**
- **can be repaired without added risk to a ship's mission, and**
- **provide the best long-term value.**

The principles provided here apply to the acquisition and life cycle support of CI/NDI for all PEO TSC programs. Tailor each CI/NDI acquisition process on a case-by-case basis.

Section 1.3 COTS Refresh

One of the most difficult problems in maintaining and sustaining a COTS-based system over an unknown period of time is the decision of when to upgrade or replace the key COTS products that are facing end of sale (EOS) concerns. This decision becomes crucial when planning and establishing ship supportable windows for a configuration over a known period of time. One of the primary objectives is to always ensure that any given ship COTS configuration is supportable. Industry generally cannot control the frequency or the content of COTS releases and their product line truncations in the commercial sectors. COTS configuration Management takes on a new and different of controlling ones destiny. The timing of and their fast paced introduction tends to and independent of the new release of other components in the system. Changes in the requirements for the system are not always with COTS product upgrades.
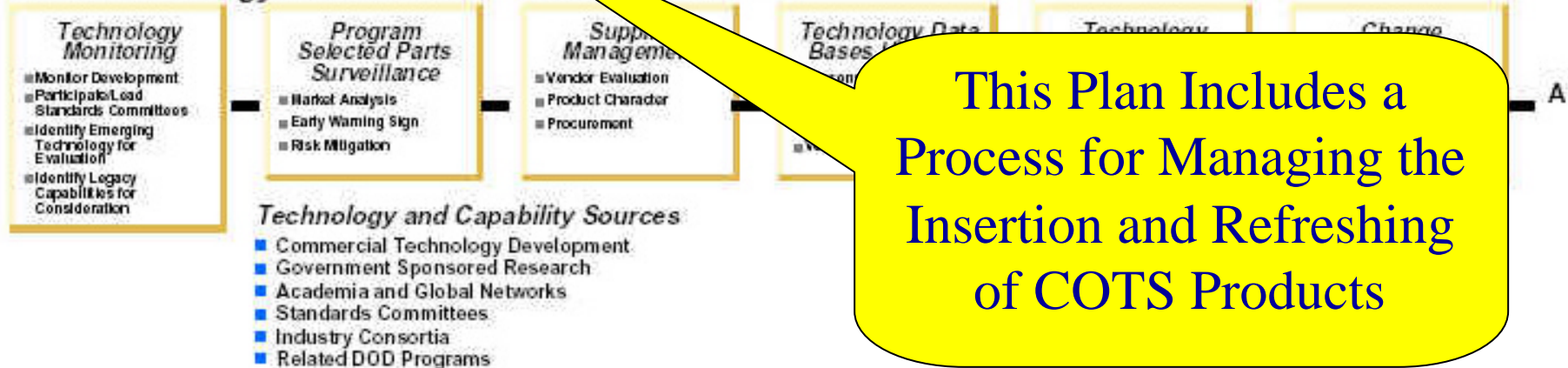
New releases of COTS products can occur as months and typically not longer than 2 years upgrade to the latest version or plan ahead

Aegis has Developed A Migration Plan to Manage the Long Term Maintenance of COTS Products

- Loss of supplier support for prior versions that are installed and in use.
- The inability to buy new copies or obtain licenses for additional copies of the version that is already in the system.
- Inadequate sparing profile, dependent on DMS parts
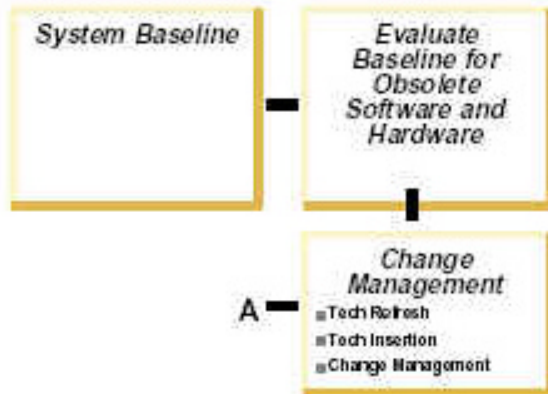- Over abundant sparing profile based on life time buys

COTS Technology Insertion and Refresh Process

COTS Technology Assessment - Continuous Process

Technology Monitoring
- Monitor Development
- Participate/Lead Standards Committees
- Identify Emerging Technology for Evaluation
- Identify Legacy Capabilities for Consideration

Program Selected Parts Surveillance
- Market Analysis
- Early Warning Sign
- Risk Mitigation

Supp... Manageme...
- Vendor Evaluation
- Product Character
- Procurement

Technology Data Bases...

Technology...

Change...

A

Technology and Capability Sources
- Commercial Technology Development
- Government Sponsored Research
- Academia and Global Networks
- Standards Committees
- Industry Consortia
- Related DOD Programs

> This Plan Includes a Process for Managing the Insertion and Refreshing of COTS Products

Obsolescence Management

System Baseline

Evaluate Baseline for Obsolete Software and Hardware

Change Management
- Tech Refresh
- Tech Insertion
- Change Management

A

Iterative Technology Alternative Analysis and Design

Identify Technology Alternatives
- COTS
- Product Development
- Technology Reuse Candidates

Assess System Update Needs
- Requirement Updates
- Operability Needs
- Weapon Upgrades
- Sensor Upgrades
- Supportability
- TOC Constraints

Product Evaluation and Selection
- Evaluate COTS Alts.
- Measure TPMs
- Assess Operability Impacts
- Assess Supportability Impacts
- Prototype

Develop Updated Baseline
- TOC Process
- Update Tech. Refresh Plan
- Define Block Change
- Update Training Plans
- Design, Test, Integrate System

Update Engineering Databases
- System Baseline
- Change Mgmt Process
- Simultaneous Models
- Cost Models
- TOC Process

Iterative Process
- Driven by Technology Changes
- Initiated by Change Management Process
- Considers Program Specific Requirements
- Bounded by TOC Constraints

Figure 1-COTS Refresh Process

COTS Obsolescence Management Implementation Concept

And Existing Processes are Modified to Address the Impact of COTS Obsolescence
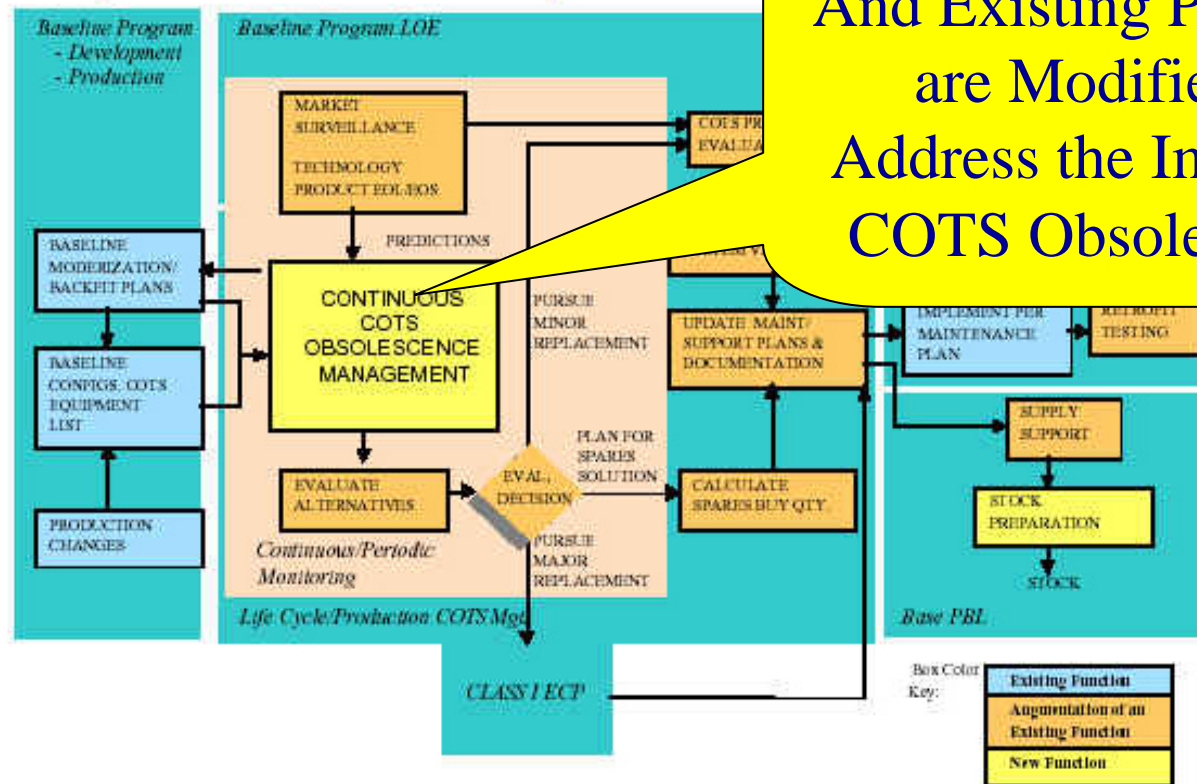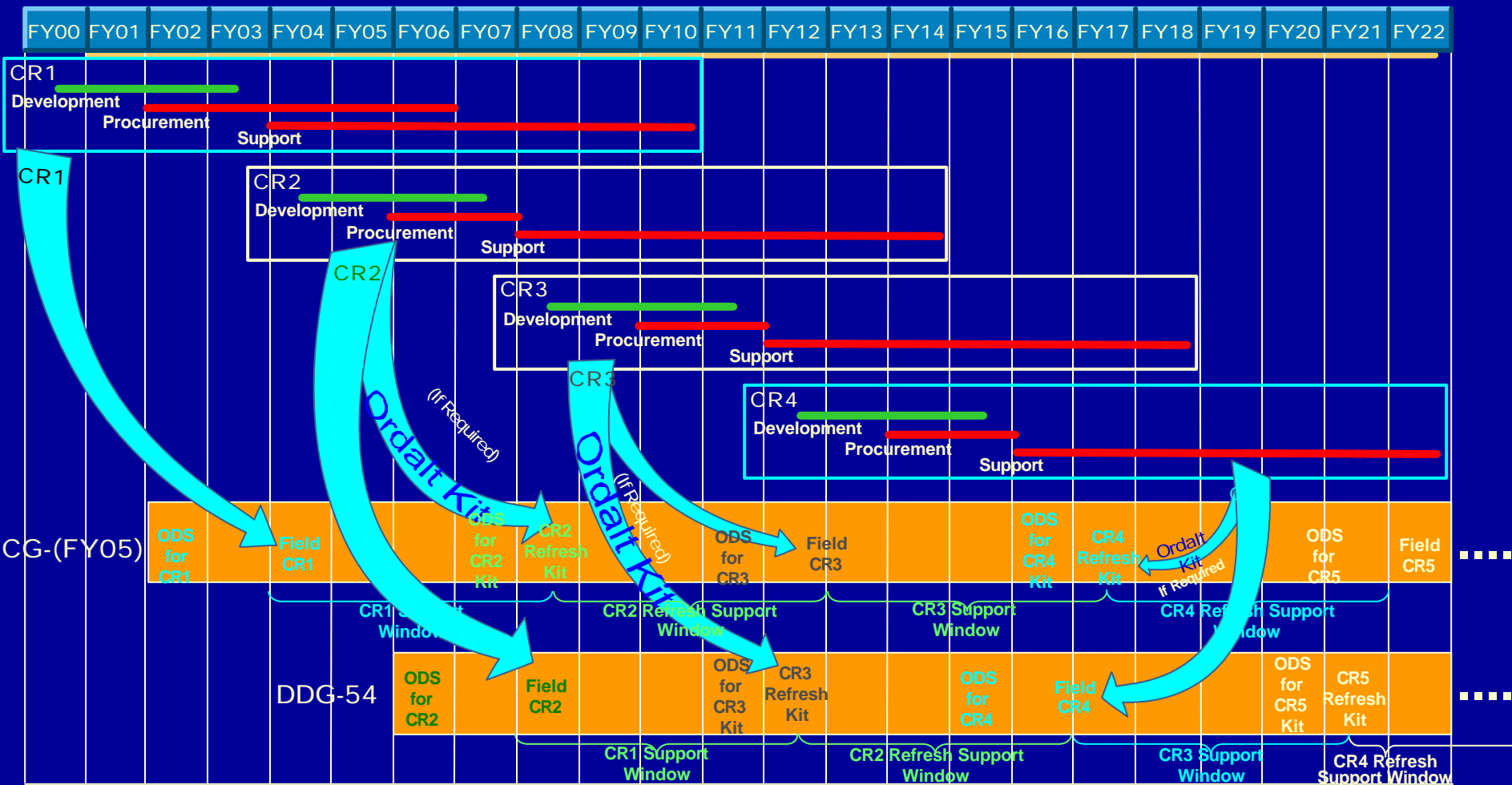
Figure 12-COTS Obsolescence Management

This process builds on the existing development, production, integration, life-time support, and performance based logistics contracts, and the diminishing manufacturing source (DMS) process rather than create a totally new process. As shown in Figure 11, some of the steps in the process currently exist, others need to be augmented to handle the unique requirements of COTS equipment, and other process steps are new and unique to COTS equipment management. Of primary importance to any COTS management process is continuous COTS obsolescence management.

Notional COTS Refresh 20 Year Timeline

We established COTS Working Groups to be clearinghouses for all COTS issues.

- **NSWCDD Aegis CI/NDI IPT**
- **Configuration Management**
- **Processes/Documentation**
  - **Standard Operating Procedures**
- **Delivery V&V Team**

NUMBER	TITLE
N21-SOP-501-ACTS_UNIX	ACTS (UNIX) QA Build Procedures
N21-SOP-504-ADDGEN	ADDGEN QA Build Procedures
N21-SOP-505-ADS_MK2	ADS MK2 QA Build Procedures
N21-SOP-507-DBTOOL	DBTOOL QA Build Procedures
N21-SOP-508-MUST	MUST QA Build Procedures
N21-SOP-509-ORTS_CP	ORTS MK9 CP QA Build Procedures
N21-SOP-510-ORTSMK9IP	ORTSMK9/IP QA Build Procedures
N21-SOP-511-TGC	TGC QA Build Procedures
N21-SOP-512-CD_ADJUNC	C&D/ADJUNCT QA Build Procedures
N21-SOP-513-ATOE	ATOE QA Build Procedures
	CCFTS QA Build Procedures
	TIP QA Build Procedures

Documentation - SOPs (watermark)

Configuration Management (watermark)

Class	Component	Change Type/Reason	Change Vehicle	Approval	Authorization/Method	Storage	Tracking Doc/DB	Process Changes
Operating Environment	operating system	version update	IDR	Q70-DCRB,TCRB other-Elmt	N058/scheduling BUM/closure BUM	SPM Tape Library		Element, N058
		patch	FDR	Q70-DCRB,TCRB other-CRB	N058/scheduling BUM/closure BUM	Elmt, V&V		Element, V&V, N058,
	kernel	hwd driver, swap space, hostname, ip address, patches	FDR	Element	N058/scheduling BUM/closure BUM		DDD	Element, V&V
	equipment driver	upgrade, obsolete hwd	BL Upgrade, Hardware Replacement	Q70-PMS 400F other-Elmt				ACCESS
	configuration files	host table, router table	FDR	Element		V&V VOB Elmt VOB	DDD	Element, V&V
	passwords/ accounts	BL Install	Element, CPM	CPM policy	CPM Files	CPM Files	CPM	
Support Programs	layered product	version update	CRB	N058	V&V VOB	DDD, ACCESS		
	MSLB						DDD	Element, V&V, CPM
	MTT Load Base	LR, version, scenarios	PHD	ACC verification	SPM Tape Library	DDD		Verification Process - NEW
	installation procedure		build memo	Element	CPM	CPM Files	DDD	Element, CPM
	script file	ugradation, accrual, operator convenience	build memo	DCRB, CRB, Element	N058	V&V VOB	DDD	Element, SCM, V&V

Identify Issues (watermark)

```
ISSUES From Dudash Brief on 18 June 2001: OOE Component
Management

1.Look at SSDS, etc. for IPs, MACs. other COTS

2.LM has group working COTS different from CM field

3.LM made mods to vendor-delivered COTS items for 6PI. How about BL 6PIII?

4.Need to work with LM to establish same configurations at both ATTs.

5.For BL6PIII, LM is producing a Release Memo w/all changes to OEs. Can the
process deal with contingencies and exceptions for BL6PIII?

6.BL 6PIII has C++ in Multiple Elements - Is this necessary?

7.How do we track problems in the DCRB for Q70s that aren't being fixed?

8.Should OE problems be in ACCESS?

9.What should N61/N41's role and responsibility in tracking OE problems?

10.N61 will track problems for C&D/ADS; N13 for SPY & WCS. Is this OK?

11.N21 will add ship run procedures to get IP and MAC addresses and provide to
N21 1-3 weeks before delivery. How is process documented?

12.Why doesn't N27 do ship audits of IPs and MACs?

13.Who will verify that components in ship's stores will work when installed?
```

Tools To Manage COTS Products

- **TUF/X - Tactical Utilities Function for X-Windows**
  - Provides system access control, configuration protection, and automation of complex maintenance tasks to the ADS, Q-70 Consoles, and NGP
  - Session manager for operators logged onto the NGP
- **ANTT - Aegis Network Test Tool**
  - Determines the physical, network, and application level status of the LANs
- **MSLBGen - Master Server Load Base Generator**
  - Builds/links the Master Server Load Base for C2 Application and OE
- **ASVADS - Automated Software Verification And Distribution Software**
  - Ensures all Q70 equipment has the correct software
  - Can download and install software upgrades
- **MTT - Maintenance Technician Tool**
  - Provides an HTML interface to step the sailor through configure COTS equipment
- **HPOpenview/NNM - Network Node Manager**
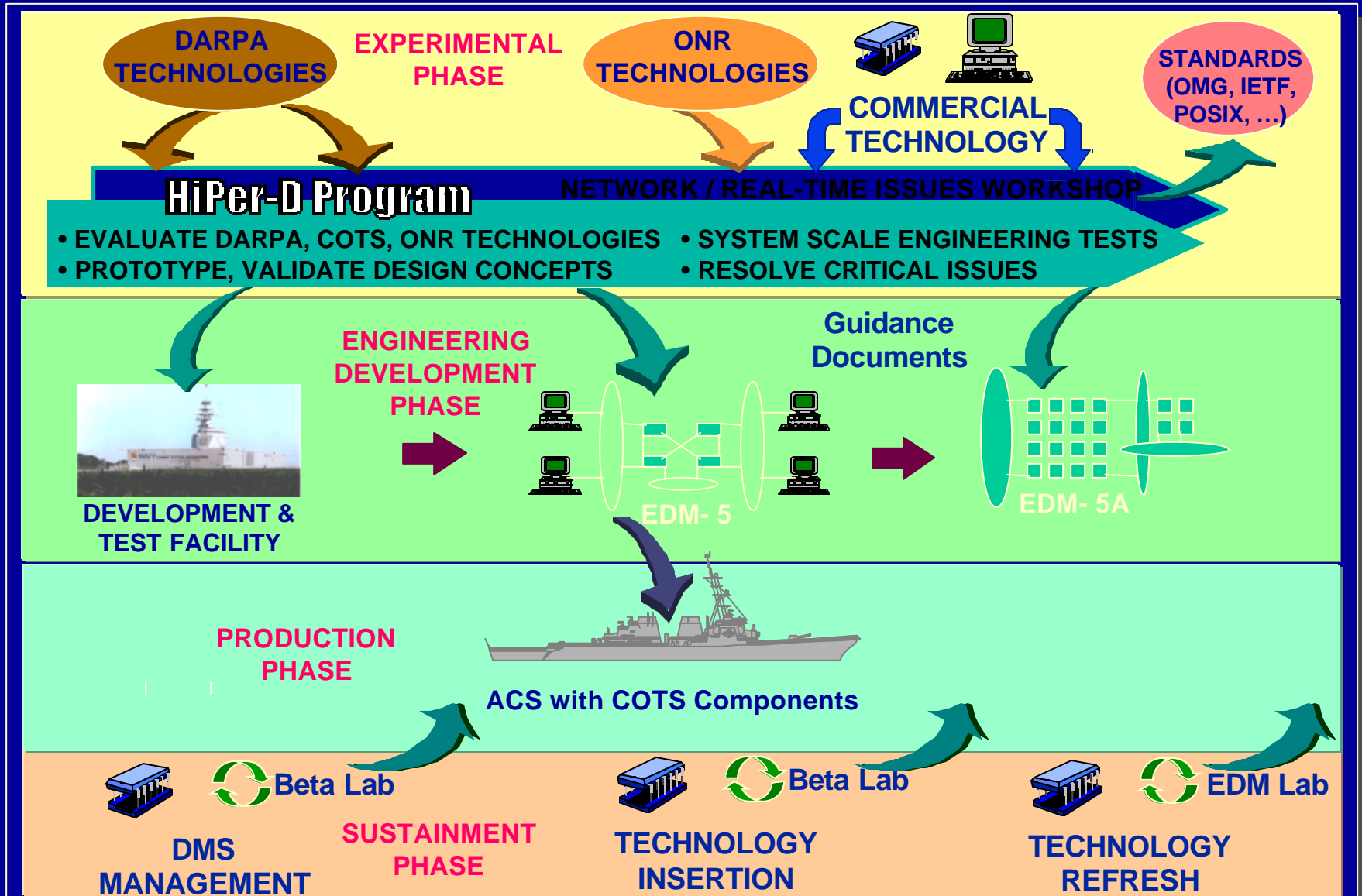 - Verify Status of Local Area Networks

Loading programs over LANs, Testing and Debugging Require Different Tools

COTS – Technical Challenge

- **Testbeds**

- **Certification**

- **Security**
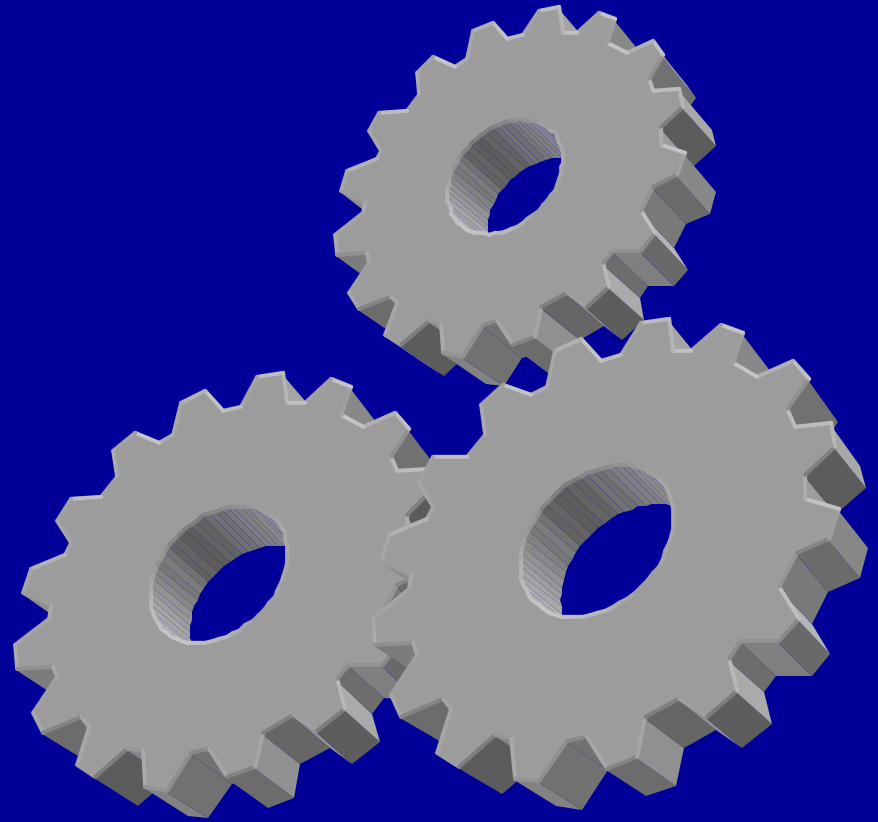
Layered COTS Test Beds

Certification

- Traditionally, Certification focused on the application software – the MIL Spec equipment was supported and tested by another Navy organization.
    - Equipment was well defined, computers and replacement parts were identical.
    - Code was Unit Tested and Inspected

- With COTS, Certification has been expanded to include the operating environment and computing equipment.
    - Testing is critical to understanding the features available, determining what changed and the effects on the system.
        – Too large to inspect or completely test
        – Large amounts of code are present but unused
    - Replacing a board, other components or operating environment changes requires reassessment and possibly re-certification

Accountability Remains with Navy

Security

- **Legacy code was developed in-house with a team whose members possessed clearances**

- **Most COTS products have been developed in an open corporate environment**

- **This places an added burden on the testing & certification team to ensure that the COTS software does not have malicious or easily compromised code**
  - **Viruses**
  - **Trojan Horses**
 - **Phone home features**

Completing the Transition…

- **What we have accomplished:**
    - **COTS-based Computing Infrastructure (LAN, Processors, OS, MW, …)**
    - **Robust Development Environment (compilers, tools, monitors, …)**
    - **Multiple cycles of Technology Refresh**
- **What we still endure:**
    - **Present SW architecture is characterized by tight coupling:**
        - **System upgrades and maintenance is difficult and expensive**
        - **System integration is complex and time-consuming**
    - **COTS H/W and S/W has become a major part of the Aegis Weapon System**
        - **Rapid COTS Technology cycle and related DMS issues present major cost and supportability issues for the Aegis fleet**
- **What we want – "Aegis Open Architecture":**
    - **Provide a Foundation for Rapid Introduction of War-fighting Improvements**
    - **Reduce Cycle Time - Development & Maintenance**
    - **Reduce Computer Program Maintenance Cost**
    - **Reduce the Impact of COTS Refreshes**
    - **Facilitate Manning Reduction Through HSI Improvements**

Summary

- **COTS provides Computational Resources - potential increased functionality, usability and improved operator interfaces**

- **We have learned a lot about the issues and possible solutions to COTS introduction in the Combat System**

- **We have demonstrated the need for**
  - **A new System Architecture to facilitate COTS utilization**
  - **Maintenance Concerns to be addressed in Development**

Our Sailors Come Home
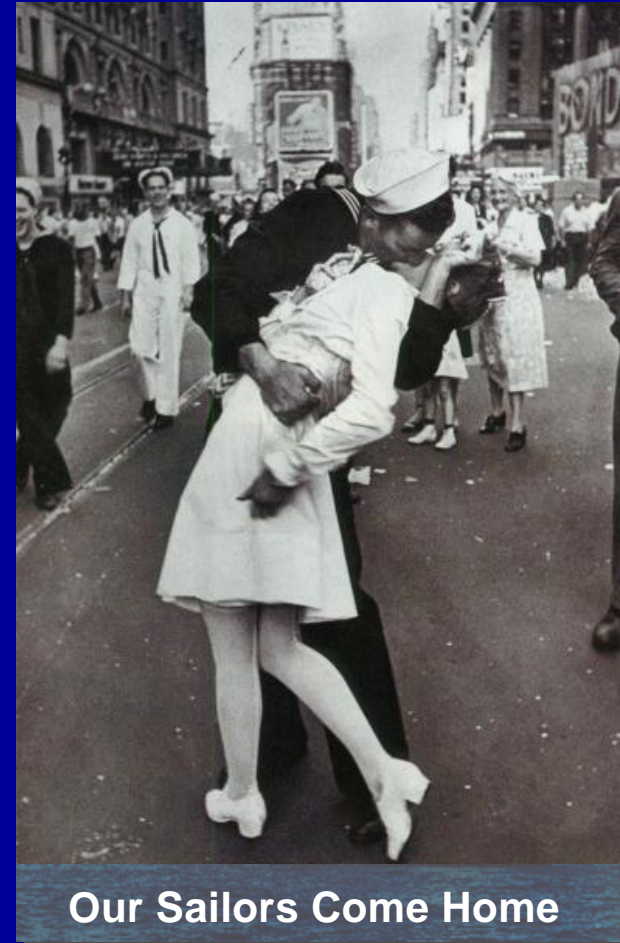
With Planning, Engineering And Funding, The Major COTS Issues Are Manageable

AWS Computer Architecture Evolution

- ❑ Legacy MIL-STD equipment and developmental executive system supported Aegis stringent real-time needs
  - ❑ Aegis used standard Navy special purpose computing plants
  - ❑ Fixed computing capacity became a constraint
  - ❑ As a result, functionality was often added were it would "fit" – not necessarily where it "belonged"
- ❑ COTS products have been used to replace MIL-STD
  - ❑ First step: Introduction of COTS-based computing adjuncts
  - ❑ Second step: Introduction of a full COTS-based computing environment
    - ❑ Software "converted" to run in new environment
    - ❑ Software not re-implemented to be modular, decoupled, scaleable, maintainable, reusable

CMS-2	CMS-2	CMS-2, Ada, C++	CMS-2, more Ada & C++	Ada, C++	C++, Java
MIL Spec (AN/UYK-7)	MIL Spec (AN/UYK-43)	MIL Spec + Adjunct COTS Processors	MIL Spec more Adjunct COTS Processors	Commercial, LAN-based, Mixed (Symmetric Multi-Processor and Single Board Computer) Architecture	Commercial, Full Distributed, Single Board Computer Architecture

| 1980 | 1985 | 1990 | 1995 | 2000 | 2005 |